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THE MECHANICAL PROPERTY DATA BASE FROM AN AIR FORCE/INDUSTRY COOPERATIVE TEST PROGRAM ON ADVANCED ALUMINUM ALLOYS (8090-T8771 PLATE)

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Materials Directorate
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Air Force Materiel Command
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A mechanical property data base on Alcan produced aluminum-lithium alloy 8090 plate was developed. Mechanical property data consisted of tension, compression, bearing, shear, and fracture toughness properties. Fatigue, fatigue crack growth and spectrum crack growth data were generated.

14. SUBJECT TERMS				15. NUMBER OF PAGES
Tensile	Bearing	2091	Fatigue Crack Growth	47
8090	Shear	AL905XL	Weldalite TM049	16. PRICE CODE
Aluminum-Lithium	Compression	IN905XL	Spectrum	
	Toughness			

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PREFACE

This report was prepared by the Materials Engineering Branch (WL/MLSE), Systems Support Division, Materials Directorate, Wright Laboratory, Wright-Patterson Air Force Base, Ohio, under Project 2418, "Metallic Structural Materials," Task 241807, "Systems Support," Work Unit 24180703, "Engineering and Design Data."

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SECTION 1

INTRODUCTION

High performance aerospace systems are dependent on materials that are lighter, have improved mechanical properties, and/or offer a cost savings. Aluminum alloys that met these criteria were the newly developed aluminum-lithium alloys and the second generation powder metallurgy alloys.

In 1985, the Air Force along with the aerospace community found it important to investigate the potential of these promising aluminum alloys. A cooperative program was formed by the Wright Laboratory Materials Directorate, Systems Support Division and a number of aerospace industries. The Air Force would obtain the test material from the producers, compile the test data, and submit reports to the participants. The participants agreed to support the program by performing mechanical property tests which includes tension, compression, bearing, shear, fracture toughness, and fatigue related properties (S/N, da/dn). The Air Force elected to perform spectrum fatigue crack growth testing on most alloys. A list of participants is shown in the following table.

This Interim report contains the aluminum-lithium alloy 8090-T8771 1.75-inch plate produced by Alcan. Comparisons to other materials and ranking of materials are generally avoided since each potential application may be based on different evaluation criteria.

TABLE

Participants and Advanced Aluminum Alloys in the Cooperative Test Program

	ALUMINUM LITHIUM ALLOYS														P/M ALUMINUM ALLOYS					
	PECHINEY				ALCAN			IncoMAP	ALCOA				REYNOLDS		KAISER		ALCOA			
PARTICIPANTS	2091 – T3 Sheet (0.063")	2091 – T351 Plate (0.420")	2091 – T8 Forging	8090 – T651 Extrusion	8090 – T651 Extrusion	8090 – T8771 Plate (1.75")	8090 – T8771 Plate (1.75")	PM IN9053XL Forging	PM AL9053XL Forging	2091 – T3 Sheet (0.063")	2091 – T3 Sheet (0.144")	2091 – T8 Plate (0.50")	8090 Extrusion	Weldalite 049 RX815 Plate (0.5")	7064 – T74511 Extrusion	7064 – T74 Forging	CW67 Sheet (0.063")	CW67 Plate (0.40")	CW67 Extrusion	CW67 Forging
Air Force WPAFB, OH		x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
Army, MA													x	x						
AVCO, TN										x										
Boeing, WA	x	x	x	x																
Douglas Aircraft, CA									x	x	x	x	x	x						
General Dynamics, CA	x	x								x	x	x		x						
General Dynamics, TX	x	x	x	x				x		x	x	x	x							
Grumman Aerospace, NY	x	x			x			x							x	x			x	x
Jet Propulsion, CA									x					x						
Lockheed, CA	x			x					x	x		x								
Lockheed, GA			x		x					x	x					x				x
LTV, TX	x			x				x	x	x			x		x	x			x	
Martin Marietta, LA	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x
McDonnell Douglas Astro, CA											x			x						
McDonnell Douglas Helicopter, AR									x											
McDonnell Douglas Missile Sys, MO														x						
McDonnell Aircraft, MO	x							x	x	x						x	x			x
NASA, VA					x			x	x					x						
Naval Air Development Center		x		x					x			x								x
Northrop, CA	x	x	x		x	x	x	x	x	x	x	x	x	x						
Sikorsky, CT								x		x						x		x		x
Sundstrand, IL														x						
Wyman – Gordon									x											

SECTION 2

MATERIALS AND TESTS

The Alcan aluminum-lithium alloy 8090-T8771 1.75-inch plate was received May 1991. The 8090 was tested in the as-received condition by Martin Marietta and the Air Force.

Mechanical properties (tension, compression, bearing shear and fracture toughness), fatigue and constant amplitude fatigue crack growth tests were performed according to ASTM standards, unless otherwise specified. Spectrum fatigue crack growth tests were performed by the Air Force using FALSTAFF (a severe fatigue environment) and Mini-TWIST (a moderately intense fatigue environment) spectrums.

SECTION 3

PRESENTATION

Each participant compiled a data package which contained the data they generated. Some of these data packages contain discussion, and in other cases, only the data were provided. The tensile, compression, bearing, shear and fracture toughness data are put in tabular form. Fatigue, fatigue crack growth and spectrum fatigue crack growth data were put in tabular and graphical form.

SECTION 4

RESULTS AND DISCUSSION

The data generated by the participants on the 8090 plate are shown in Tables F1 thru F25 and Figures F1 thru F12.

SECTION 5

CONCLUSIONS

Two aerospace laboratories participated in generating data on the Alcan 8090-T8771 Plate for the cooperative test program. These data combined with previous interim reports on the Air Force/Industry Cooperative Test Program on Advanced Aluminum Alloys provide an extensive data base on aluminum-lithium alloys.

TABLE F1

TENSILE RESULTS AT t/2 LOCATION FOR
ALCAN 8090-T8771 PLATE (1.75" THICK)

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	E (MSI)
MARTIN	RT	LONG	79.1	71.0	5.0	3.9	
MARIETTA			79.1	71.2	5.0	9.6	
			79.3		5.0	3.5	
AIR FORCE	RT	LONG	76.7	65.7	8.1	9.2	
			80.2	72.6	5.5	5.2	
			76.7	66.0	7.9	11.6	
		AVERAGE	78.5	69.3	6.1	7.2	
	STANDARD DEVIATION		1.5	3.2	1.5	3.4	

TABLE F2

TENSILE RESULTS AT t/2 LOCATION FOR
ALCAN 8090-T8771 PLATE (1.75" THICK)

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	E (MSI)
AIR FORCE	RT	45	72.3	54.7	11.5	17.6	
			72.4	58.0	8.9	14.5	
			72.5	55.5	9.8	15.4	
		AVERAGE	72.4	56.1	10.0	15.8	
	STANDARD DEVIATION		0.1	1.7	1.3	1.6	

TABLE F3

TENSILE RESULTS AT t/2 LOCATION FOR
ALCAN 8090-T8771 PLATE (1.75" THICK)

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	E (MSI)
MARTIN	RT	L TRANS	78.2	66.9	6.0	8.1	
MARIETTA			78.1	66.8	6.0	8.9	
			78.5	67.1	6.0	8.5	
AIR FORCE	RT	L TRANS	73.3	56.9	10.4	10.3	
			79.5	68.4	6.5	9.7	
			73.8	57.3	10.5	11.2	
		AVERAGE	76.9	63.9	7.6	9.4	
	STANDARD DEVIATION		2.7	5.3	2.2	1.2	

TABLE F4

TENSILE RESULTS AT t/2 LOCATION FOR
ALCAN 8090-T8771 PLATE (1.75" THICK)

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	E (MSI)
AIR FORCE	RT	S TRANS	75.6	61.4	1.7	2.4	
			75.0	61.0	3.5	2.4	
			75.8	62.0	5.4	5.1	
		AVERAGE	75.4	61.5	3.5	3.3	
	STANDARD DEVIATION		0.4	0.5	1.8	1.6	

TABLE F5

COMPRESSION RESULTS AT t/2 LOCATION FOR
ALCAN 8090-T8771 PLATE (1.75" THICK)

COMPANY	TEST TEMPERATURE (DEGREES F)	ORIENTATION	COMPRESSIVE YIELD STRENGTH (KSI)	COMPRESSIVE MODULUS (KSI)
MARTIN	RT	LONG	70.3	12.1
MARIETTA			67.0	12.1
			68.1	12.1
AIR FORCE	RT	LONG	62.5	11.8
			63.9	12.0
			60.5	10.1
		AVERAGE	65.4	11.7
		STANDARD DEVIATION	3.7	0.8

TABLE F6

COMPRESSION RESULTS AT t/2 LOCATION FOR
ALCAN 8090-T8771 PLATE (1.75" THICK)

COMPANY	TEST TEMPERATURE (DEGREES F)	ORIENTATION	COMPRESSIVE YIELD STRENGTH (KSI)	COMPRESSIVE MODULUS (KSI)
MARTIN	RT	L TRANS	72.6	12.2
MARIETTA			73.6	12.0
			73.1	12.1
AIR FORCE	RT	L TRANS	62.5	11.8
			70.9	12.0
			67.5	11.9
		AVERAGE	70.0	12.0
		STANDARD DEVIATION	4.3	0.1

TABLE F7

COMPRESSION RESULTS AT t/2 LOCATION FOR
ALCAN 8090-T8771 PLATE (1.75" THICK)

COMPANY	TEST TEMPERATURE (DEGREES F)	ORIENTATION	COMPRESSIVE YIELD STRENGTH (KSI)	COMPRESSIVE MODULUS (KSI)
MARTIN	RT	S TRANS	69.6	12.1
MARIETTA			68.8	12.0
			68.5	12.0
		AVERAGE	69.0	12.0
		STANDARD DEVIATION	0.6	0.1

TABLE F8

AMSLER DOUBLE SHEAR RESULTS AT t/2 LOCATION FOR
ALCAN 8090-T8771 PLATE (1.75" THICK)

COMPANY	ORIENTATION	SHEAR STRENGTH (KSI)
AIR FORCE	T-L	41.1
		41.8
		43.4
		44.4
		43.6
		41.4
	AVERAGE	42.6
	STANDARD DEVIATION	1.4

TABLE F9

BEARING RESULTS AT t/2 LOCATION FOR
ALCAN 8090-T8771 PLATE (1.75" THICK)

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
AIR FORCE	LONG	1.5	112.1	90.6
			112.8	91.5
			106.9	83.7
		AVERAGE	110.6	88.6
		STANDARD DEVIATION	3.2	4.3

TABLE F10

BEARING RESULTS AT t/2 LOCATION FOR
ALCAN 8090-T8771 PLATE (1.75" THICK)

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
AIR FORCE	L TRANS	1.5	109.9	89.6
			112.7	90.6
			105.7	87.3
		AVERAGE	109.4	89.2
		STANDARD DEVIATION	3.5	1.7

TABLE F11

FRACTURE TOUGHNESS RESULTS FOR
ALCAN 8090-T8771 PLATE (1.75" THICK)

COMPANY	ORIENTATION	KIC (KSI in^0.5)	Kq (KSI in^0.5)	COMMENT
MARTIN MARIETTA	L-T		29.9	(1)
			27.9	(1)
			28.3	(1)
AIR FORCE	L-T		24.7	(2)
			23.7	(2)
		27.0		
	AVERAGE	27.0	26.9	
	STANDARD DEVIATION	0.0	2.6	

(1): INVALID DUE TO a/W < 0.45
(2): INVALID DUE TO Pmax/Pq > 1.1

TABLE F12

FRACTURE TOUGHNESS RESULTS FOR
ALCAN 8090-T8771 PLATE (1.75" THICK)

COMPANY	ORIENTATION	KIC (KSI in^0.5)	Kq (KSI in^0.5)	COMMENT
MARTIN MARIETTA	S-L		11.1	(1)
			11.0	(1)
AIR FORCE	S-L		12.1	(1)
			12.8	(1)
			9.9	(1),(2)
	AVERAGE		11.8	
	STANDARD DEVIATION		0.9	

(1): INVALID DUE TO Kfat/Kq > 0.6
(2): INVALID DUE TO a,B < 2.5(Kq/YS)^2

TABLE F13

FRACTURE TOUGHNESS RESULTS FOR
ALCAN 8090-T8771 PLATE (1.75" THICK)

COMPANY	ORIENTATION	KIC (KSI in^0.5)	Kq (KSI in^0.5)	COMMENT
MARTIN MARIETTA	T-L		21.0	(1)
			20.1	(1)
AIR FORCE	T-L	25.0		
		24.3		
		22.7		
	AVERAGE	24.0	20.6	
	STANDARD DEVIATION	1.2	0.6	

(1): INVALID DUE TO Kfat/Kq > 0.6

TABLE F14

FRACTURE TOUGHNESS RESULTS FOR
ALCAN 8090-T8771 PLATE (1.75" THICK)

COMPANY	ORIENTATION	KIC (KSI in^0.5)	Kq (KSI in^0.5)	COMMENT
MARTIN MARIETTA	S-T		13.1	(1)
	AVERAGE		13.1	
	STANDARD DEVIATION		0.0	

(1): INVALID DUE TO Kfat/Kq > 0.6

TABLE F15

FATIGUE RESULTS WITH R=0.1 AND Kt=1.0 FOR
ALCAN 8090-T8771 PLATE (1.75" THICK)

COMPANY	ORIENTATION	STRESS (KSI)	CYCLES
AIR FORCE	LONG	73.5	5,016
		69.0	15,020
		66.0	16,366
		60.0	36,998
		57.0	93,383
		50.8	280,000
		48.0	95,642
		43.5	2,946,918
		37.5	17,000,000 *
		29.0	10,000,000 *

(*): RUN OUT

TABLE F16

FATIGUE RESULTS WITH R=0.1 AND Kt=3.0 FOR
ALCAN 8090-T8771 PLATE (1.75" THICK)

COMPANY	ORIENTATION	STRESS (KSI)	CYCLES
AIR FORCE	LONG	50.0	3,822
		40.0	7,994
		30.0	32,103
		28.0	39,796
		26.0	74,224
		24.0	64,517
		22.0	135,951
		21.0	648,867
		20.5	103,502
		20.0	10,000,000 *

(*): RUN OUT

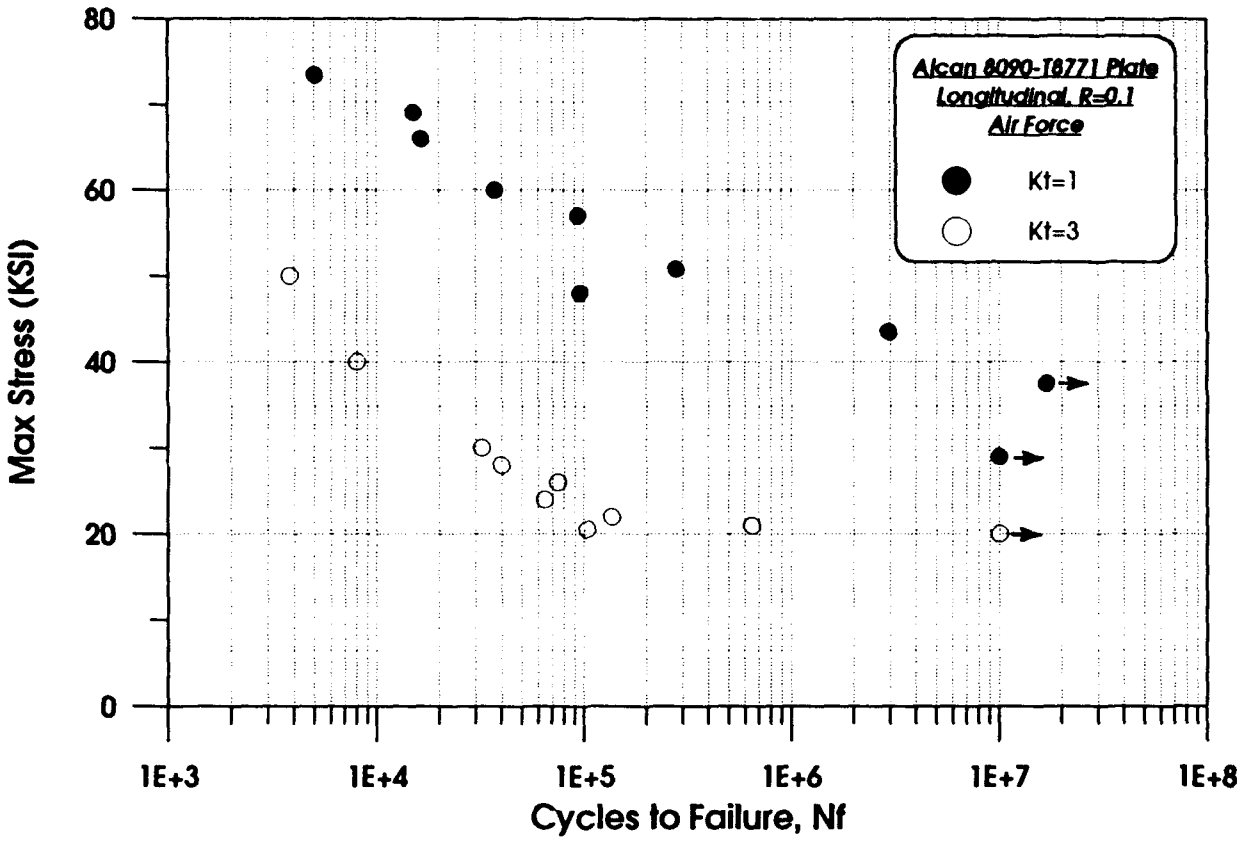

FIGURE F1. Fatigue Results for 8090-T8771 Plate (Longitudinal Orientation). Air Force.

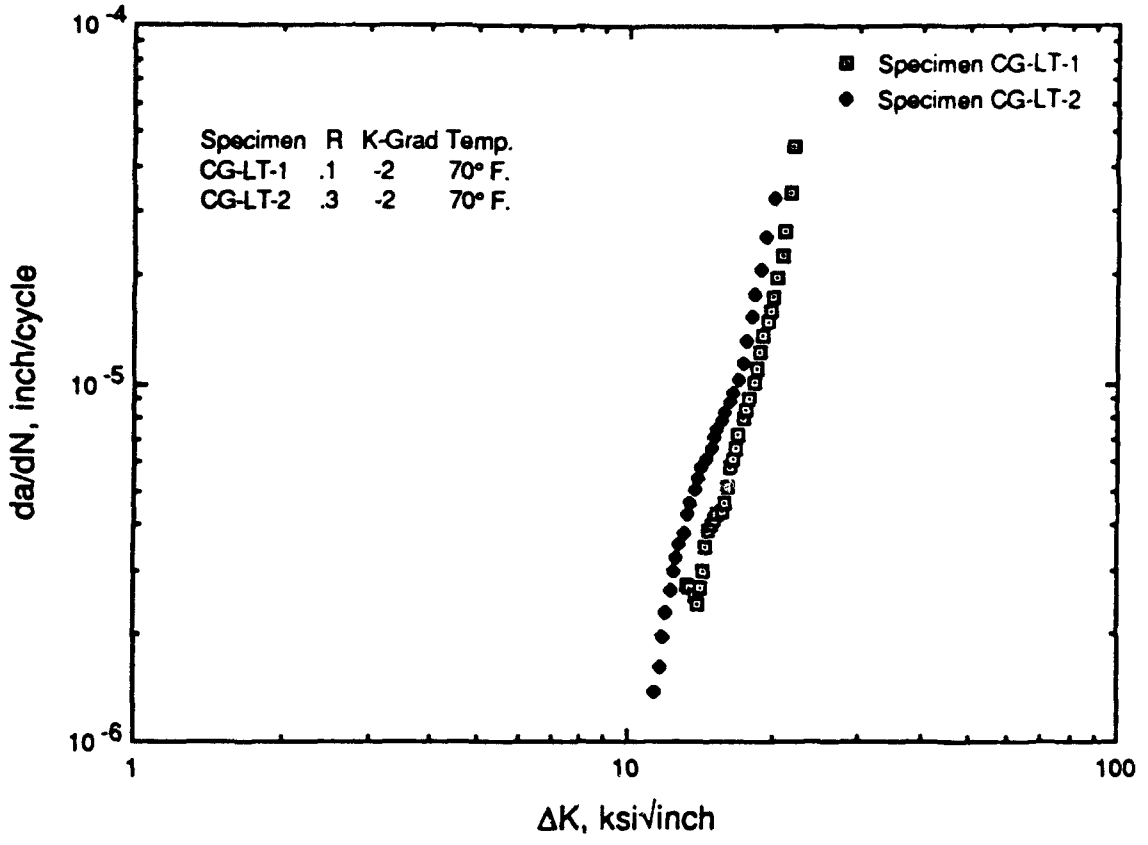

FIGURE F2. Fatigue Crack Growth Rate Data for 8090-T8771 Plate (L-T Orientation). Martin Marietta.

TABLE F17

Fatigue Crack Growth Rate Data Associated with
Figure F2 (Specimen CG-LT-1)

Tests were performed with the "CGR Crack Growth Program" from Interlaken Version 1.0B.
Strengths are in PSI. Loads in pounds. Dimensions in inches. Temperature in Degrees Fahrenheit. dK in psi sqrt inch.
The crack lengths were corrected based on the final measurments. The data was averaged using the 7 pt. polynomial method.
The precrack Pmax load of 2875 lbs. was 6.8% higher than the initial Pmax test load of 2446 lbs.

Operator:	cpm
Sample date:	09-24-91
Material:	8090 Al-Li
ID #:	CG-LT-1
Yield Strength:	71110
Modulus of Elast:	11100000
COD Pos:	2
Crack Plane:	L-T
Geometry:	1
Width:	2.0035
Thickness:	1.001
Half span (MT):	.1
Env:	AIR
Temp:	70
Humidity:	50
Waveform:	1
Test Frequency:	10
Test Type:	1
K Gradient:	-2
Min Load:	270
Max Load:	2700
Test Mode:	1
Data Pt Intvl:	.01
Min Growth Rate:	.00001
Compl Slope:	2
Pts/Cycle:	200
Upper Slope Limit:	85
Lower Slope Limit:	15
No of Slopes Ave:	5
Compliance Cor.:	1.01186
Notch Length:	.804
Precrack Length:	.892
Precrack Cycles:	95360
Precrack Max Load:	2874.94
Precrack Min Load:	283.341
#Points:	40

TABLE F17 Continued

#Points: 40				
cycle	crack length	dA/dN	dK	Delta Load
76	.81807	0	0	2446.02
7687	.827839	0	0	2431.85
11622	.837417	0	0	2429.41
16621	.847308	2.73482e-6	13341.6	2430.87
17016	.857309	2.74944e-6	13378.2	2428.92
21521	.867043	2.678e-6	13622.4	2430.39
25456	.876509	2.55124e-6	13808.4	2430.39
29962	.886573	2.40983e-6	13993.8	2429.41
34874	.896374	2.67777e-6	14239.5	2431.36
37578	.905701	2.99468e-6	14373.	2430.39
40855	.915003	3.49581e-6	14580.9	2430.87
43805	.924823	3.89369e-6	14815.8	2431.36
45858	.934519	4.03748e-6	14983.	2429.9
48074	.944946	4.21119e-6	15198.9	2429.9
50372	.954235	4.33896e-6	15428.7	2430.39
52833	.964569	4.38178e-6	15659.4	2429.9
55293	.974571	4.67815e-6	15910.7	2430.87
57427	.984776	5.17769e-6	16146.	2429.9
59238	.994184	5.80673e-6	16382.4	2430.39
60801	1.00372	6.16529e-6	16634.7	2431.85
62365	1.01396	6.59573e-6	16884.2	2429.9
63602	1.02362	7.22593e-6	17103.3	2429.9
65247	1.03348	7.97268e-6	17438.7	2430.39
66486	1.04331	8.4522e-6	17729.2	2431.36
67396	1.05402	9.04237e-6	17958.	2432.34
68552	1.0638	1.00304e-5	18294.9	2432.83
69626	1.07315	1.10796e-5	18619.3	2431.85
70374	1.08258	1.22187e-5	18850.5	2429.9
71203	1.09293	1.35224e-5	19194.1	2429.9
71869	1.10246	1.47645e-5	19525.2	2431.36
72454	1.112	1.58668e-5	19824.3	2431.85
73120	1.12168	1.75657e-5	20185.2	2428.92
73623	1.13112	1.96805e-5	20523.9	2432.34
74126	1.1409	2.26089e-5	20831.3	2429.9
74548	1.15039	2.67701e-5	21254.3	2431.36
74970	1.16217	3.40151e-5	21720.9	2433.32
75310	1.17278	4.57042e-5	22056.1	2432.34
75569	1.18441	0	0	2431.36
75828	1.19962	0	0	2433.32
76005	1.2165	0	0	2434.29

TABLE F18

Fatigue Crack Growth Rate Data Associated
with Figure F2 (Specimen CG-LT-2)

Tests were performed with the "CGR Crack Growth Program" from Interlaken Version 1.0B.
Strengths are in PSI. Loads in pounds. Dimensions in inches. Temperature in Degrees Fahrenheit. dK in psi sqrt inch.
The crack lengths were corrected based on the final measurments. The data was averaged using the 7 pt. polynomial method.
The precrack Pmax load of 2875 lbs. was 6.8% higher than the initial Pmax test load of 1936 lbs.

Operator:	cpm
Sample date:	09-24-91
Material:	8090 Al-Li
ID #:	CG-LT-2
Yield Strength:	71110
Modulus of Elast:	11100000
COD Pos:	2
Crack Plane:	L-T
Geometry:	1
Width:	2.003
Thickness:	1
Half span (MT):	.1
Env:	AIR
Temp:	70
Humidity:	50
Waveform:	1
Test Frequency:	10
Test Type:	1
K Gradient:	-2
Min Load:	810
Max Load:	2700
Test Mode:	1
Data Pt Intvl:	.01
Min Growth Rate:	.00001
Compl Slope:	2
Pts/Cycle:	200
Upper Slope Limit:	85
Lower Slope Limit:	15
No of Slopes Ave:	5
Compliance Cor.:	1.06142
Notch Length:	.8035
Precrack Length:	.897
Precrack Cycles:	66865
Precrack Max Load:	2874.94
Precrack Min Load:	862.237
#Points:	36

TABLE F18 Continued

#Points:		36		
cycle	crack length	dA/dN	dK	Delta Load
76	.891065	0	0	1936.49
169	.90337	0	0	1896.43
13388	.914341	0	0	1891.55
22926	.925698	1.38423e-6	11527.9	1891.06
31815	.93633	1.62176e-6	11725.2	1890.08
38017	.946829	1.95346e-6	11894.8	1889.11
42836	.957324	2.30119e-6	12063.3	1889.59
47326	.967997	2.64268e-6	12276.8	1892.04
51251	.978596	2.99747e-6	12477.5	1892.04
54847	.990381	3.27357e-6	12675.3	1889.59
58281	1.00171	3.58152e-6	12920.	1891.55
60900	1.01242	3.85038e-6	13124.9	1893.01
64008	1.02339	4.29105e-6	13355.5	1890.08
66382	1.03392	4.64784e-6	13594.2	1892.53
68676	1.04479	5.08078e-6	13838.6	1893.5
70644	1.05635	5.44453e-6	14064.9	1891.55
72776	1.06732	5.85194e-6	14341.3	1891.06
74419	1.07784	6.16975e-6	14577.6	1891.06
76223	1.08847	6.60149e-6	14861.	1892.04
77784	1.09948	7.08273e-6	15124.8	1891.06
79346	1.11034	7.45266e-6	15419.6	1890.57
80663	1.12107	7.86935e-6	15709.6	1892.04
81979	1.13184	8.25386e-6	16009.4	1892.53
83377	1.14275	8.83869e-6	16351.3	1892.53
84531	1.15341	9.46722e-6	16655.9	1892.53
85685	1.16417	1.0335e-5	16991.7	1891.55
86676	1.17499	1.15143e-5	17354.6	1894.48
87667	1.18639	1.32648e-5	17722.9	1892.53
88496	1.19695	1.53373e-5	18106.9	1892.04
89162	1.20782	1.78032e-5	18478.7	1892.04
89745	1.21887	2.09292e-5	18887.2	1894.48
90329	1.2306	2.56765e-5	19370.7	1894.97
90832	1.24363	3.3126e-5	19961.9	1894.48
91172	1.25502	0	0	1898.39
91430	1.26608	0	0	1897.9
91688	1.28	0	0	1896.43

TABLE F18 Continued

36

#Points: cycle	crack length	dA/dN	dK	Delta Load
76	.891065	0	0	1936.49
169	.90337	0	0	1896.43
13388	.914341	0	0	1891.55
22926	.925698	1.38423e-6	11527.9	1891.06
31815	.93633	1.62176e-6	11725.2	1890.08
38017	.946829	1.95346e-6	11894.8	1889.11
42836	.957324	2.30119e-6	12063.3	1889.59
47326	.967997	2.64268e-6	12276.8	1892.04
51251	.978596	2.99747e-6	12477.5	1892.04
54847	.990381	3.27357e-6	12675.3	1889.59
58281	1.00171	3.58152e-6	12920.	1891.55
60900	1.01242	3.85038e-6	13124.9	1893.01
64008	1.02339	4.29105e-6	13355.5	1890.08
66382	1.03392	4.64784e-6	13594.2	1892.53
68676	1.04479	5.08078e-6	13838.6	1893.5
70644	1.05635	5.44453e-6	14064.9	1891.55
72776	1.06732	5.85194e-6	14341.3	1891.06
74419	1.07784	6.16975e-6	14577.6	1891.06
76223	1.08847	6.60149e-6	14861.	1892.04
77784	1.09948	7.08273e-6	15124.8	1891.06
79346	1.11034	7.45266e-6	15419.6	1890.57
80663	1.12107	7.86935e-6	15709.6	1892.04
81979	1.13184	8.25386e-6	16009.4	1892.53
83377	1.14275	8.83869e-6	16351.3	1892.53
84531	1.15341	9.46722e-6	16655.9	1892.53
85685	1.16417	1.0335e-5	16991.7	1891.55
86676	1.17499	1.15143e-5	17354.6	1894.48
87667	1.18639	1.32648e-5	17722.9	1892.53
88496	1.19695	1.53373e-5	18106.9	1892.04
89162	1.20782	1.78032e-5	18478.7	1892.04
89745	1.21887	2.09292e-5	18887.2	1894.48
90329	1.2306	2.56765e-5	19370.7	1894.97
90832	1.24363	3.3126e-5	19961.9	1894.48
91172	1.25502	0	0	1898.39
91430	1.26608	0	0	1897.9
91688	1.28	0	0	1896.43

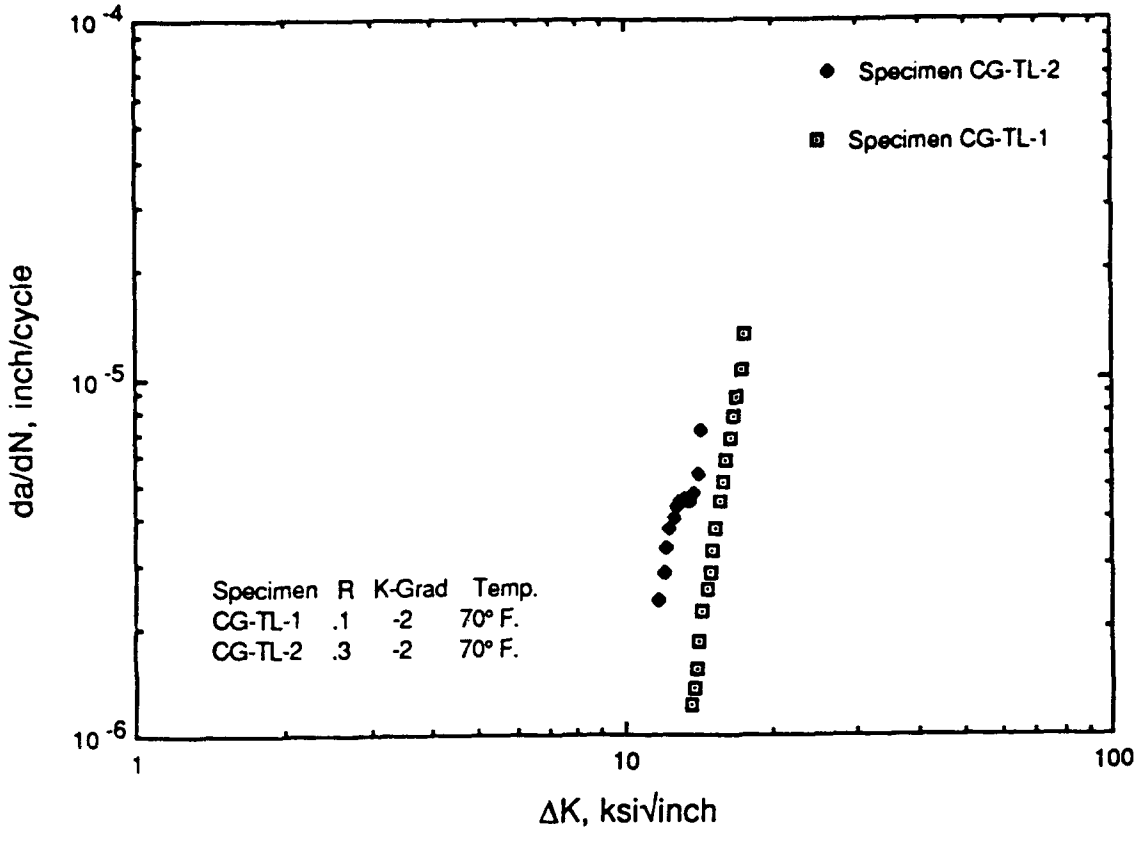

FIGURE F3. Fatigue Crack Growth Rate Data for 8090-T8771 Plate (T-L Orientation). Martin Marietta.

TABLE F19

Fatigue Crack Growth Rate Data Associated with Figure F3 (Specimen CG-TL-1)

Tests were performed with the "CGR Crack Growth Program" from Interlaken Version 1.0B.
Strengths are in PSI. Loads in pounds. Dimensions in inches. Temperature in Degrees Fahrenheit. dK in psi sqrt inch.
The crack lengths were corrected based on the final measurments. The data was averaged using the 7 pt. polynomial method.
The precrack Pmax load of 2875 lbs. was 6.8% higher than the initial Pmax test load of 2702 lbs.

Operator:	cpm/ncd
Sample date:	09-24-91
Material:	8090 Al-Li
ID #:	CG-T1-1
Yield Strength:	66350
Modulus of Elast:	11250000
COD Pos:	2
Crack Plane:	T-L
Geometry:	1
Width:	2.0033
Thickness:	1
Half span (MT):	.1
Env:	AIR
Temp:	70
Humidity:	50
Waveform:	1
Test Frequency:	10
Test Type:	1
K Gradient:	-2
Min Load:	270
Max Load:	2700
Test Mode:	1
Data Pt Intvl:	.01
Min Growth Rate:	.00001
Compl Slope:	2
Pts/Cycle:	200
Upper Slope Limit:	85
Lower Slope Limit:	15
No of Slopes Ave:	5
Compliance Cor.:	1.08362
Notch Length:	.8053
Precrack Length:	.9004
Precrack Cycles:	138379
Precrack Max Load:	2874.94
Precrack Min Load:	283.341
#Points:	23

cycle	crack length	dA/dN	dK	Delta Load
76	.900405	0	0	2430.42
12579	.911	0	0	2430.39
23676	.859997	0	0	2430.39
33387	.870441	3.17097e-7	13797.2	2429.9
40247	.879966	7.94854e-7	13771.6	2430.39
47432	.88989	1.53814e-6	14070.7	2427.94
54616	.900886	1.82145e-6	14304.	2429.41
60905	.911076	2.20956e-6	14545.	2429.9
64912	.921716	2.53571e-6	14730.1	2429.9
68511	.931403	2.84312e-6	14937.3	2430.87
72030	.941803	3.26489e-6	15168.5	2430.39
75385	.952745	3.77042e-6	15407.3	2429.41
78412	.963555	4.46241e-6	15685.3	2430.87
80544	.974279	5.08879e-6	15911.2	2430.87
82757	.985828	5.85625e-6	16195.5	2430.87
84644	.997562	6.75067e-6	16470.5	2428.92
86450	1.00981	7.77325e-6	16791.7	2428.92
87848	1.02061	8.72143e-6	17090.7	2429.41
89165	1.03342	1.03738e-5	17412.8	2429.41
90237	1.0442	1.32296e-5	17748.	2431.36
91146	1.05395	0	0	2431.36
91731	1.0653	0	0	2430.87
92151	1.0773	0	0	2431.85

TABLE F20

Fatigue Crack Growth Rate Data Associated with Figure F3 (Specimen CG-TL-2)

Tests were performed with the "CGR Crack Growth Program" from Interlaken Version 1.0B.
Strengths are in PSI. Loads in pounds. Dimensions in inches. Temperature in Degrees Fahrenheit. dK in psi sqrt inch.
The crack lengths were corrected based on the final measurments. The data was averaged using the 7 pt. polynomial method.
The precrack Pmax load of 2875 lbs. was 6.8% higher than the initial Pmax test load of 2702 lbs.

Operator:	cpm
Sample date:	09-24-91
Material:	8090 Al-Li
ID #:	CG-TL-2
Yield Strength:	66850
Modulus of Elast:	11250000
COD Pos:	2
Crack Plane:	T-L
Geometry:	1
Width:	2.003
Thickness:	1.001
Half span (MT):	.1
Env:	AIR
Temp:	70
Humidity:	50
Waveform:	1
Test Frequency:	10
Test Type:	1
K Gradient:	-2
Min Load:	810
Max Load:	2700
Test Mode:	1
Data Pt Intvl:	.01
Min Growth Rate:	.00001
Compl Slope:	2
Pts/Cycle:	200
Upper Slope Limit:	85
Lower Slope Limit:	15
No of Slopes Ave:	5
Compliance Cor.:	1.07341
Notch Length:	.8035
Precrack Length:	.9215
Precrack Cycles:	123206
Precrack Max Load:	2874.94
Precrack Min Load:	862.237
#Points:	19

cycle	crack length	dA/dN	dK	Delta Load
76	.909805	0	0	1962.38
10687	.920906	0	0	1889.11
17714	.931758	0	0	1891.55
22701	.94231	2.37086e-6	11807.6	1891.55
27281	.953011	2.85092e-6	12007.1	1892.04
30963	.964681	3.3215e-6	12208.7	1893.01
34320	.97642	3.74497e-6	12420.5	1892.53
37024	.986889	4.03343e-6	12628.5	1893.01
39483	.997977	4.28854e-6	12811.9	1890.57
42187	1.00979	4.45745e-6	13055.4	1890.57
44645	1.02063	4.52734e-6	13280.8	1889.59
46697	1.031	4.49661e-6	13493.4	1891.55
49075	1.04121	4.52118e-6	13715.1	1890.08
51372	1.05164	4.71378e-6	13954.5	1892.53
53828	1.06194	5.30214e-6	14194.	1890.57
56122	1.0731	7.0252e-6	14493.7	1891.55
57764	1.08461	0	0	1892.04
58917	1.09475	0	0	1891.06
59582	1.107	0	0	1894.48

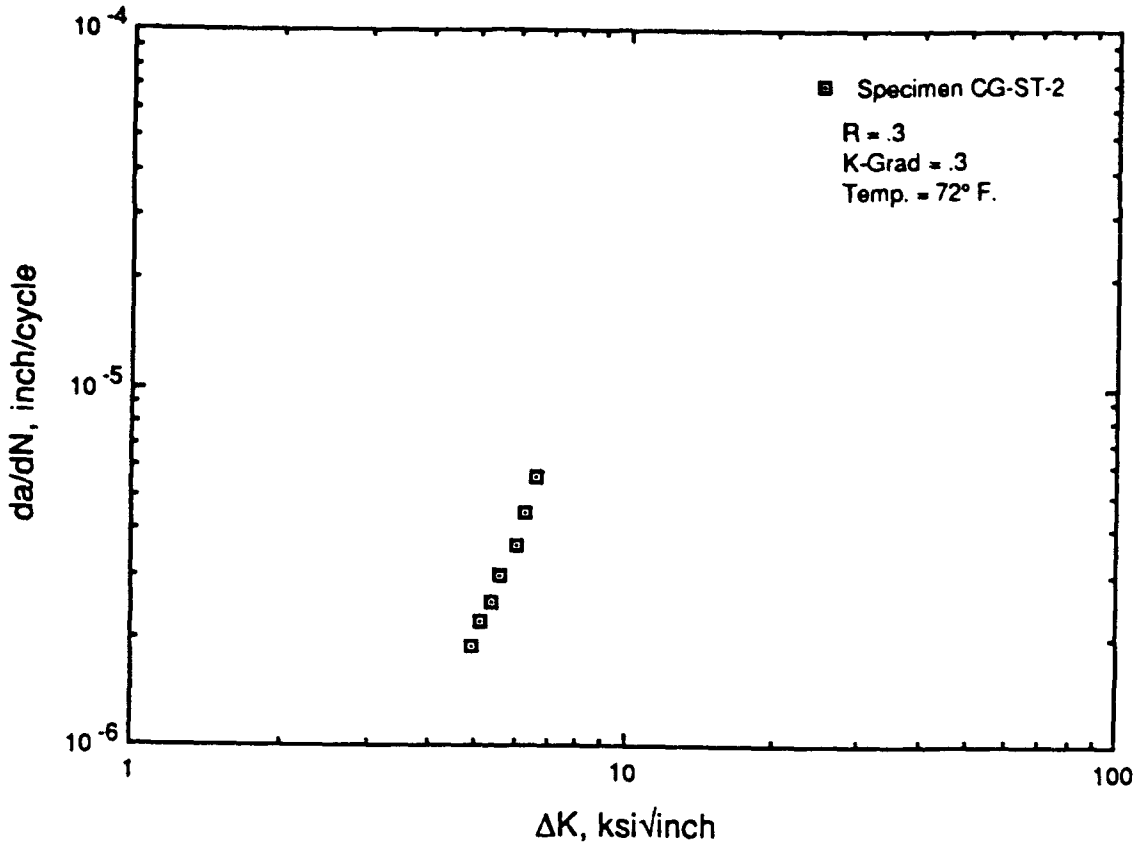

FIGURE F4. Fatigue Crack Growth Rate Data for 8090-T8771 Plate (S-T Orientation). Martin Marietta.

TABLE F21

Fatigue Crack Growth Rate Data Associated with
Figure F4 (Specimen CG-ST-2)

Tests were performed with the "CGR Crack Growth Program" from Interlaken Version 1.0B.
Strengths are in PSI. Loads in pounds. Dimensions in inches. Temperature in Degrees Fanrenheit. dK in psi sqrt inch.
The crack lengths were corrected based on the final measurments. The data was averaged using the 7 pt. polynomial method.

Operator:	Chris Miller
Sample date:	08-18-91
Material:	8090-T8771
ID #:	CG-ST-2
Yield Strength:	71000
Modulus of Elast:	11200000
COD Pos:	2
Crack Plane:	ST
Geometry:	1
Width:	1.4035
Thickness:	.701
Half span (MT):	.1
Env:	Air
Temp:	72
Humidity:	51
Waveform:	1
Test Frequency:	10
Test Type:	1
K Gradient:	-2
Min Load:	150
Max Load:	500
Test Mode:	1
Data Pt Intvl:	.01
Min Growth Rate:	.000001
Compl Slope:	3
Pts/Cycle:	200
Upper Slope Limit:	85
Lower Slope Limit:	15
No of Slopes Ave:	5
Compliance Cor.:	.985189
Notch Length:	.563
Precrack Length:	.72
Precrack Cycles:	118121
Precrack Max Load:	500
Precrack Min Load:	150
#Points:	13

cycle	crack length	dA/dN	dK	Delta Load
119	.719281	0	0	355.642
16867	.736786	0	0	354.079
29310	.754402	0	0	355.642
39292	.772179	1.86994e-6	4866.63	355.642
48502	.790093	2.15482e-6	5093.44	355.642
56445	.80808	2.47499e-6	5354.75	357.206
63860	.825916	2.96648e-6	5644.28	358.183
69901	.843877	3.64302e-6	5973.53	360.528
74887	.861517	4.52111e-6	6328.71	362.286
78421	.879265	5.58259e-6	6617.91	361.114
81529	.8968	0	0	362.677
84214	.914419	0	0	365.217
85986	.932	0	0	368.539

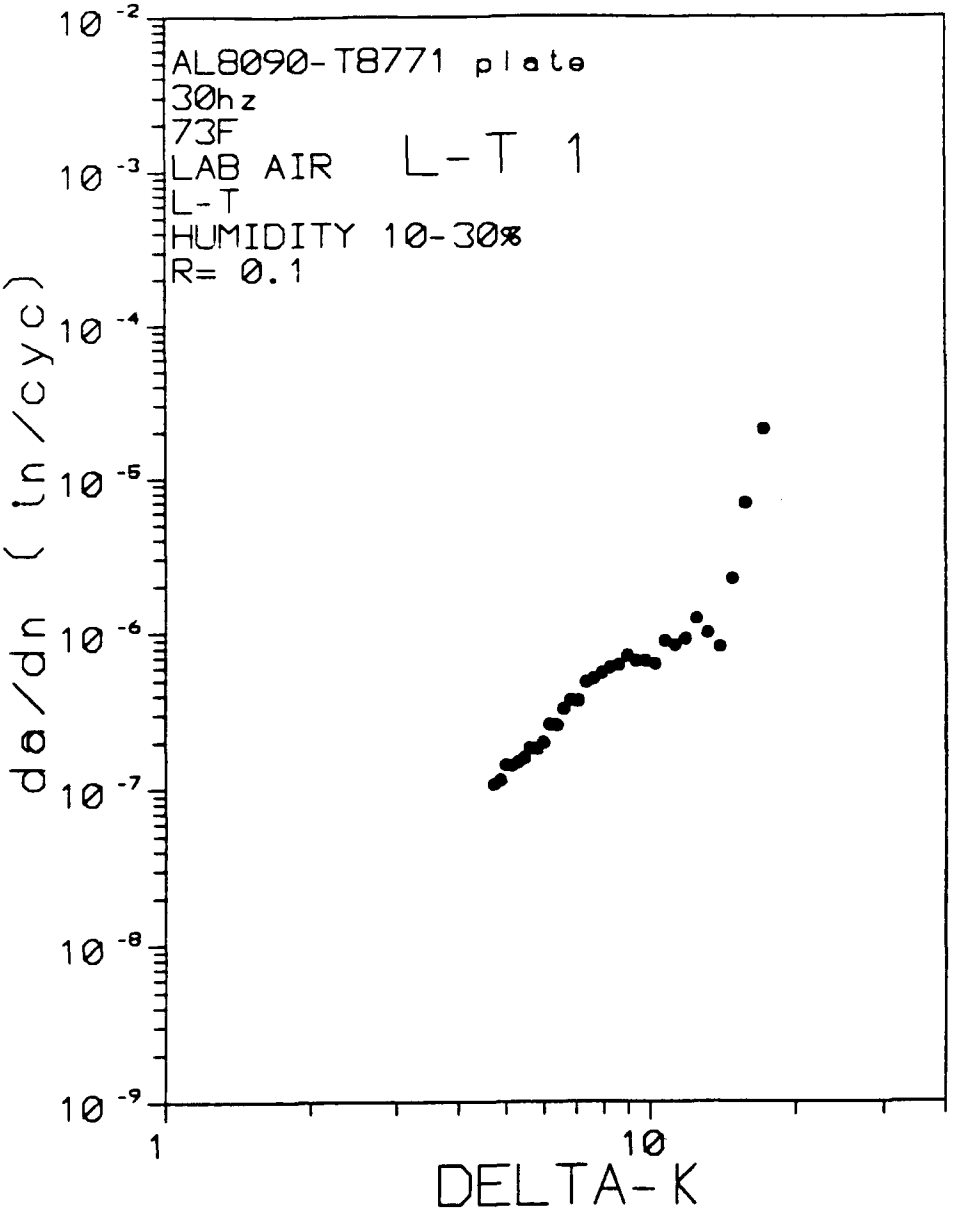

FIGURE F5. Fatigue Crack Growth Rate Data for 8090-T8771 Plate (L-T Orientation and R=0.1).
Air Force.

TABLE F22

Fatigue Crack Growth Rate Data Associated with Figure F5

MATERIAL: ALUMINUM
ALLOY: 8090
CONDITION/HT: T8771
FORM: 1.75 IN. PLATE
.2% YIELD STRENGTH (KSI): 68
ULT. STRENGTH (KSI): 77
MODULUS: 11.0
SPECIMEN TYPE: CT
ORIENTATION: L-T
SPECIMEN I.D. LT1
SPECIMEN WIDTH: 2.005
SPECIMEN THK.: .249

MAX. LOAD (LBS): 222
MIN. LOAD (LBS): 22
STRESS RATIO: 0.1
TEST FREQUENCY hz: 30
CYCLIC WAVE FORM: SINE
TEST PROCEDURE: K-INCREASING
ENVIRONMENT: LAB AIR
TEST TEMPERATURE F: 73F
RELATIVE HUMIDITY: 10-30%
MEASUREMENT INTERVAL (IN.): .020
CRACK MEASUREMENT METHOD: COMPLIANCE

a (in)	kilocycles	da/dN (in/cyc)	Del K (KSI-in^0.5)
0.566	32.00	3.17E-07	6.52
0.576	77.70	2.21E-07	6.08
0.587	132.50	1.87E-07	5.71
0.597	191.60	1.71E-07	5.43
0.607	263.20	1.41E-07	5.10
0.617	325.60	1.64E-07	4.77
0.627	399.30	1.39E-07	4.47
0.637	478.50	1.28E-07	4.19
0.647	584.40	9.65E-08	3.92
0.658	695.80	9.08E-08	3.76
0.668	845.20	6.76E-08	3.52
0.678	1079.10	4.31E-08	3.32
0.688	1456.30	2.68E-08	3.10
0.710	2807.30	6.65E-08	3.62
0.730	2988.00	1.11E-07	3.69
0.750	3160.70	1.16E-07	3.79
0.770	3298.50	1.45E-07	3.89
0.790	3439.10	1.44E-07	3.98
0.810	3571.20	1.52E-07	4.09
0.830	3694.10	1.63E-07	4.19
0.850	3801.40	1.87E-07	4.30
0.871	3910.60	1.85E-07	4.42
0.891	4009.70	2.02E-07	4.54
0.911	4086.10	2.62E-07	4.65
0.931	4162.90	2.61E-07	4.78
0.951	4224.10	3.32E-07	4.89
0.971	4276.80	3.80E-07	5.06
0.991	4329.70	3.79E-07	5.19
1.011	4370.10	4.96E-07	5.33
1.031	4408.40	5.26E-07	5.46
1.051	4443.50	5.72E-07	5.62
1.072	4476.10	6.19E-07	5.98
1.092	4507.40	6.40E-07	6.12
1.112	4534.90	7.30E-07	6.29
1.132	4564.50	6.77E-07	6.42
1.152	4594.20	6.75E-07	6.79
1.172	4625.50	6.44E-07	6.94
1.192	4647.80	9.07E-07	7.13
1.212	4671.50	8.51E-07	7.64
1.233	4693.10	9.31E-07	7.88
1.253	4709.20	1.26E-06	8.08
1.273	4729.20	1.03E-06	8.53
1.293	4753.40	8.29E-07	8.84
1.314	4762.30	2.27E-06	9.43
1.334	4765.20	6.87E-06	9.76
1.368	4766.80	2.25E-05	9.99

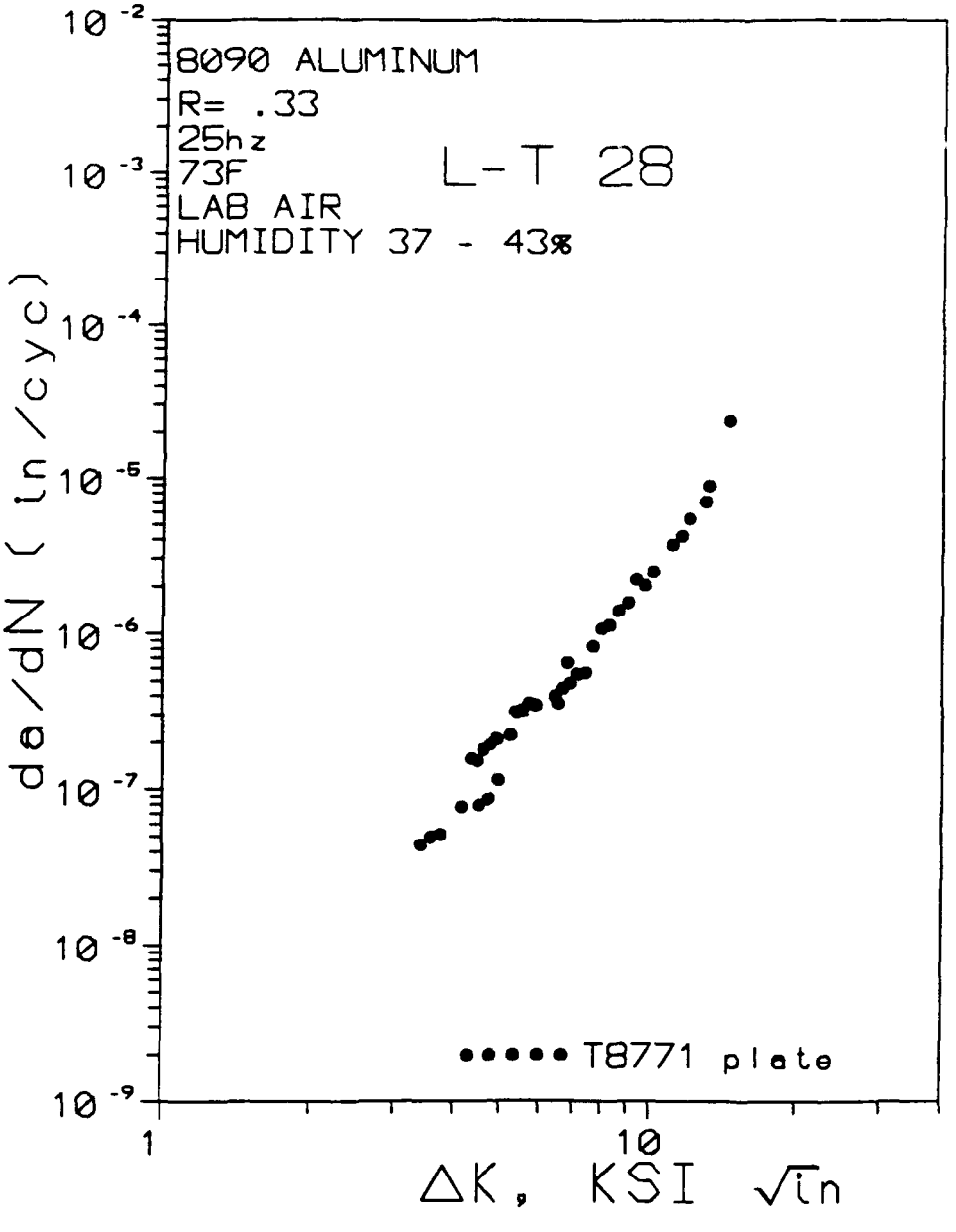

FIGURE F6. Fatigue Crack Growth Rate Data for 8090-T8771 Plate (L-T Orientation and R=0.33).
Air Force.

TABLE F23

Fatigue Crack Growth Rate Data Associated with Figure F6

MATERIAL: ALUMINUM
ALLOY: 8090
CONDITION/HT: T8771
FORM: 1.75 IN. PLATE
2% YIELD STRENGTH (KSI): 68
ULT. STRENGTH (KSI): 77
MODULUS: 11.0
SPECIMEN TYPE: CT
ORIENTATION: L-T
SPECIMEN I.D LT28
SPECIMEN WIDTH: 2.003
SPECIMEN THK.: .248

MAX.LOAD(LBS): 289
MIN. LOAD (LBS): 95
STRESS RATIO: 0.33
TEST FREQUENCY hz: 15
CYCLIC WAVE FORM: SINE
TEST PROCEDURE: K-INCREASING
ENVIRONMENT: LAB AIR
TEST TEMPERATURE F: 74
RELATIVE HUMIDITY: 36-44%
MEASUREMENT INTERVAL (IN.): .020
CRACK MEASUREMENT METHOD: COMPLIANCE

'a (in)	'cycles	'da/dN (in/cyc)	Del K (KSI-in^0.5)
0.651	1081720.00	7.74E-08	4.13
0.672	1487480.00	5.17E-08	3.74
0.683	1703550.00	4.97E-08	3.57
0.693	1932910.00	4.43E-08	3.40
0.894	3297950.00	1.57E-07	4.33
0.914	3429750.00	1.52E-07	4.46
0.935	3544860.00	1.80E-07	4.60
0.956	3655400.00	1.92E-07	4.74
0.977	3754060.00	2.10E-07	4.90
1.018	3923630.00	2.22E-07	5.22
1.038	3989040.00	3.13E-07	5.36
1.058	4051680.00	3.22E-07	5.53
1.078	4108720.00	3.55E-07	5.70
1.099	4168270.00	3.44E-07	5.88
1 119	4219330.00	3.95E-07	6.43
1.139	4264410.00	4.44E-07	6.65
1.159	4306060.00	4.82E-07	6.89
1.179	4342560.00	5.50E-07	7.11
1.199	4378020.00	5.66E-07	7.41
1.220	4402510.00	8.35E-07	7.68
1.240	4421030.00	1.08E-06	7.99
1.260	4438650.00	1.14E-06	8.28
1.281	4453290.00	1.41E-06	8.61
1.301	4466100.00	1.59E-06	9.00
1.321	4475020.00	2.25E-06	9.35
1.341	4484810.00	2.07E-06	9.72
1.362	4493080.00	2.50E-06	10.12
1.383	4498580.00	3.76E-06	11.04
1.403	4503380.00	4.29E-06	11.52
1.423	4507010.00	5.56E-06	11.96
1.444	4509900.00	7.16E-06	12.94
1.466	4512350.00	9.10E-06	13.13
1.489	4513300.00	2.41E-05	14.43

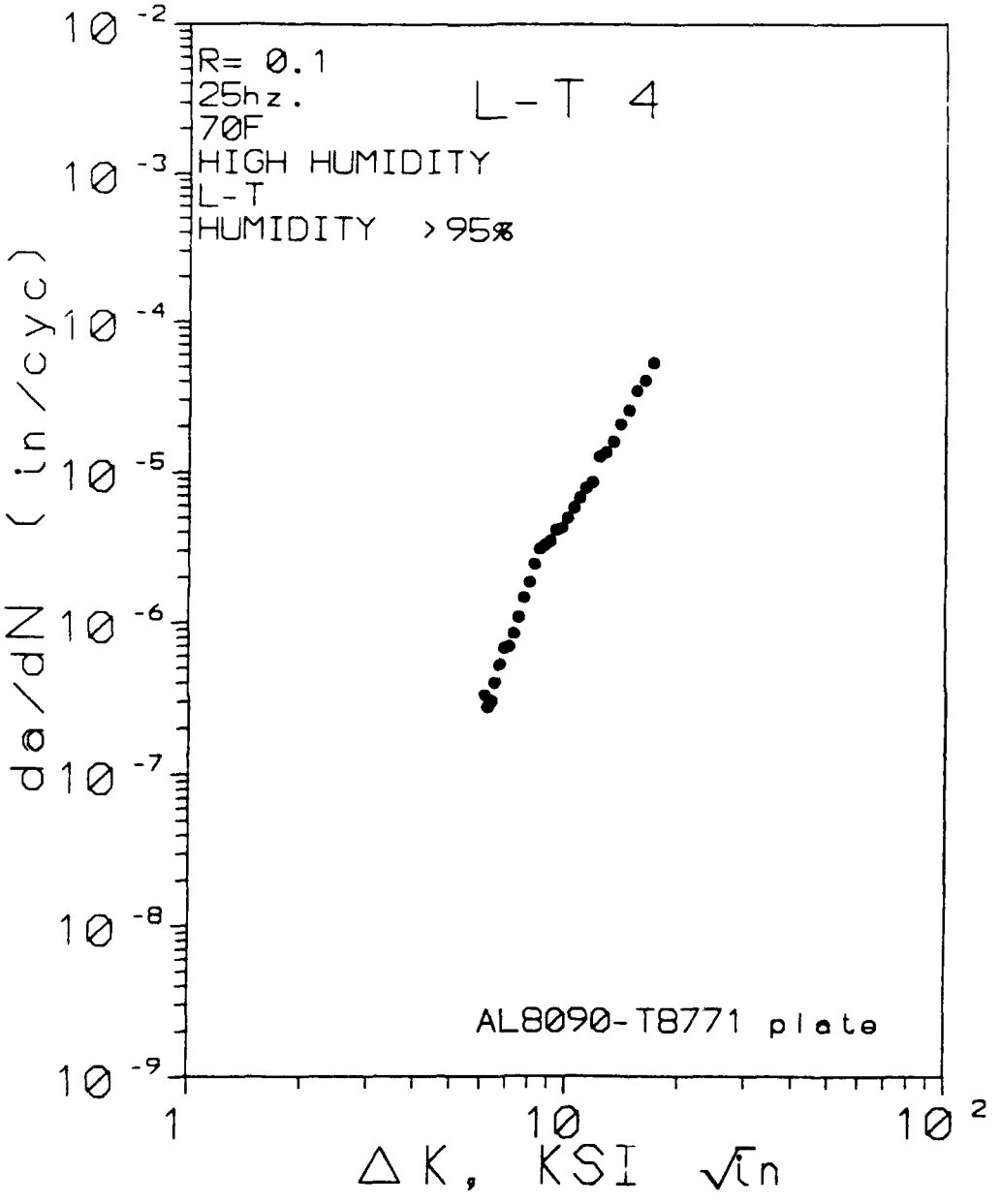

FIGURE F7. Fatigue Crack Growth Rate Data for 8090-T8771 Plate (L-T Orientation and R=0.1 and High Humidity).
Air Force.

TABLE F24

Fatigue Crack Growth Rate Data Associated with Figure F7

MATERIAL: ALUMINUM
ALLOY: 8090
CONDITION/HT: T8771
FORM: 1.75 IN. PLATE
.2% YIELD STRENGTH (KSI): 68
ULT. STRENGTH (KSI): 77
MODULUS: 11.0
SPECIMEN TYPE: CT
ORIENTATION: L-T
SPECIMEN I.D LT4
SPECIMEN WIDTH: 2.004
SPECIMEN THK.: .250

MAX. LOAD (LBS): 329
MIN. LOAD (LBS): 33
STRESS RATIO: 0.1
TEST FREQUENCY hz: 5
CYCLIC WAVE FORM: SINE
TEST PROCEDURE: K-INCREASING
ENVIRONMENT: HIGH HUMIDITY
TEST TEMPERATURE F: 70F
RELATIVE HUMIDITY: >95%
MEASUREMENT INTERVAL (IN): .020
CRACK MEASUREMENT METHOD: COMPLIANCE

'a (in)	'cycles	'da/dN (in/cyc)	Del K (KSI-in ^ 0.5)
0.806	790683.00	3.32E-07	6.13
0.816	827331.00	2.80E-07	6.21
0.836	893108.00	3.05E-07	6.34
0.856	943212.00	4.04E-07	6.51
0.876	981320.00	5.27E-07	6.69
0.896	1011050.00	6.78E-07	6.88
0.917	1040110.00	6.98E-07	7.07
0.937	1064010.00	8.52E-07	7.28
0.957	1082430.00	1.09E-06	7.50
0.978	1096220.00	1.48E-06	7.73
0.998	1106990.00	1.87E-06	7.97
1.018	1115150.00	2.47E-06	8.22
1.038	1121650.00	3.12E-06	8.49
1.058	1127710.00	3.31E-06	8.75
1.079	1133480.00	3.52E-06	9.05
1.099	1138400.00	4.18E-06	9.37
1.119	1143100.00	4.28E-06	9.70
1.139	1147140.00	4.96E-06	10.04
1.160	1150590.00	5.85E-06	10.44
1.180	1153800.00	6.82E-06	10.83
1.200	1156140.00	7.94E-06	11.26
1.220	1158450.00	8.67E-06	11.71
1.240	1160020.00	1.28E-05	12.20
1.261	1161490.00	1.37E-05	12.71
1.281	1162770.00	1.81E-05	13.28
1.302	1163760.00	2.11E-05	13.89
1.323	1164570.00	2.60E-05	14.57
1.344	1165150.00	3.52E-05	15.27
1.365	1165660.00	4.13E-05	16.05
1.386	1166060.00	5.42E-05	16.93

TABLE F25

Fatigue Crack Growth Rate Data Associated with Figure F8

MATERIAL: ALUMINUM
ALLOY: 8090
CONDITION/HT: T8771
FORM: 1.75 IN. PLATE
.2% YIELD STRENGTH (KSI): 68
ULT. STRENGTH (KSI): 77
MODULUS: 11.0
SPECIMEN TYPE: CT
ORIENTATION: L-T
SPECIMEN I.D LT27
SPECIMEN WIDTH: 2.004
SPECIMEN THK.: .248

MAX.LOAD(LBS): 249
MIN. LOAD (LBS): 82
STRESS RATIO: 0.33
TEST FREQUENCY hz: 15
CYCLIC WAVE FORM: SINE
TEST PROCEDURE: K-INCREASING
ENVIRONMENT: HIGH HUMIDITY
TEST TEMPERATURE F: 76
RELATIVE HUMIDITY: >95%
MEASUREMENT INTERVAL (IN.): .020
CRACK MEASUREMENT METHOD: COMPLIANCE

'a (in)	'cycles	'da/dN (in/cyc)	Del K (KSI-in^0.5)
0.624	132833.00	2.79E-07	4.87
0.634	177724.00	2.26E-07	4.60
0.644	232883.00	1.83E-07	4.40
0.655	313581.00	1.37E-07	4.11
0.666	397311.00	1.27E-07	3.85
0.676	508427.00	9.35E-08	3.62
0.686	641947.00	7.51E-08	3.41
0.696	760663.00	8.59E-08	3.27
0.707	983856.00	4.98E-08	3.05
0.729	1320890.00	1.11E-07	3.17
0.739	1414070.00	1.11E-07	3.21
0.750	1514790.00	1.09E-07	3.25
0.760	1601580.00	1.15E-07	3.30
0.780	1748260.00	1.37E-07	3.35
0.800	1889030.00	1.43E-07	3.44
0.821	2034240.00	1.42E-07	3.54
0.842	2179440.00	1.46E-07	3.64
0.862	2325920.00	1.38E-07	3.75
0.882	2467230.00	1.42E-07	3.84
0.902	2590830.00	1.62E-07	3.95
0.923	2714700.00	1.63E-07	4.08
0.943	2819900.00	1.91E-07	4.18
0.963	2918330.00	2.06E-07	4.31
0.983	3012330.00	2.17E-07	4.45
1.004	3101480.00	2.34E-07	4.59
1.026	3181830.00	2.67E-07	4.75
1.046	3254410.00	2.76E-07	4.90
1.066	3315480.00	3.30E-07	5.07
1.086	3378050.00	3.21E-07	5.24
1.106	3436150.00	3.52E-07	5.42
1.127	3485720.00	4.13E-07	5.61
1.147	3530230.00	4.58E-07	5.82
1.168	3562070.00	6.47E-07	6.04
1.188	3591080.00	7.04E-07	6.28
1.208	3616030.00	8.06E-07	6.53
1.228	3635920.00	1.01E-06	6.79
1.249	3650250.00	1.42E-06	7.03
1.269	3661430.00	1.83E-06	7.34
1.290	3671310.00	2.06E-06	7.64
1.310	3680800.00	2.18E-06	7.98
1.331	3688050.00	2.79E-06	8.34
1.352	3694990.00	3.05E-06	8.70
1.372	3700960.00	3.37E-06	9.10
1.392	3706060.00	4.01E-06	9.52
1.414	3710530.00	4.97E-06	9.97
1.435	3714260.00	5.59E-06	10.47
1.457	3717390.00	6.96E-06	10.95
1.479	3719930.00	8.65E-06	11.45
1.502	3722000.00	1.13E-05	11.99
1.531	3723200.00	2.41E-05	12.61

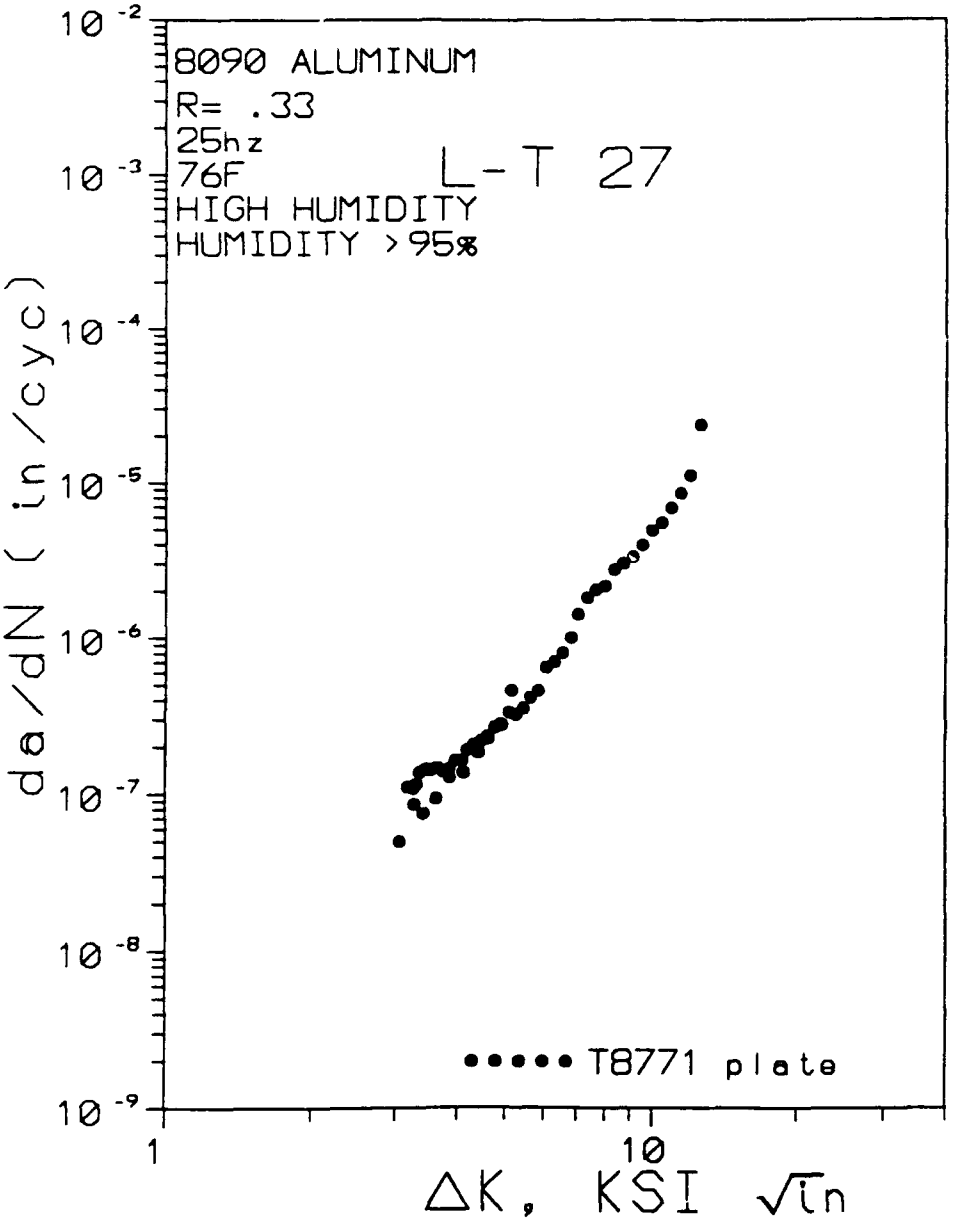

FIGURE F8. Fatigue Crack Growth Rate Data for 8090-T8771 Plate (L-T Orientation and R=0.33 and High Humidity).
Air Force.

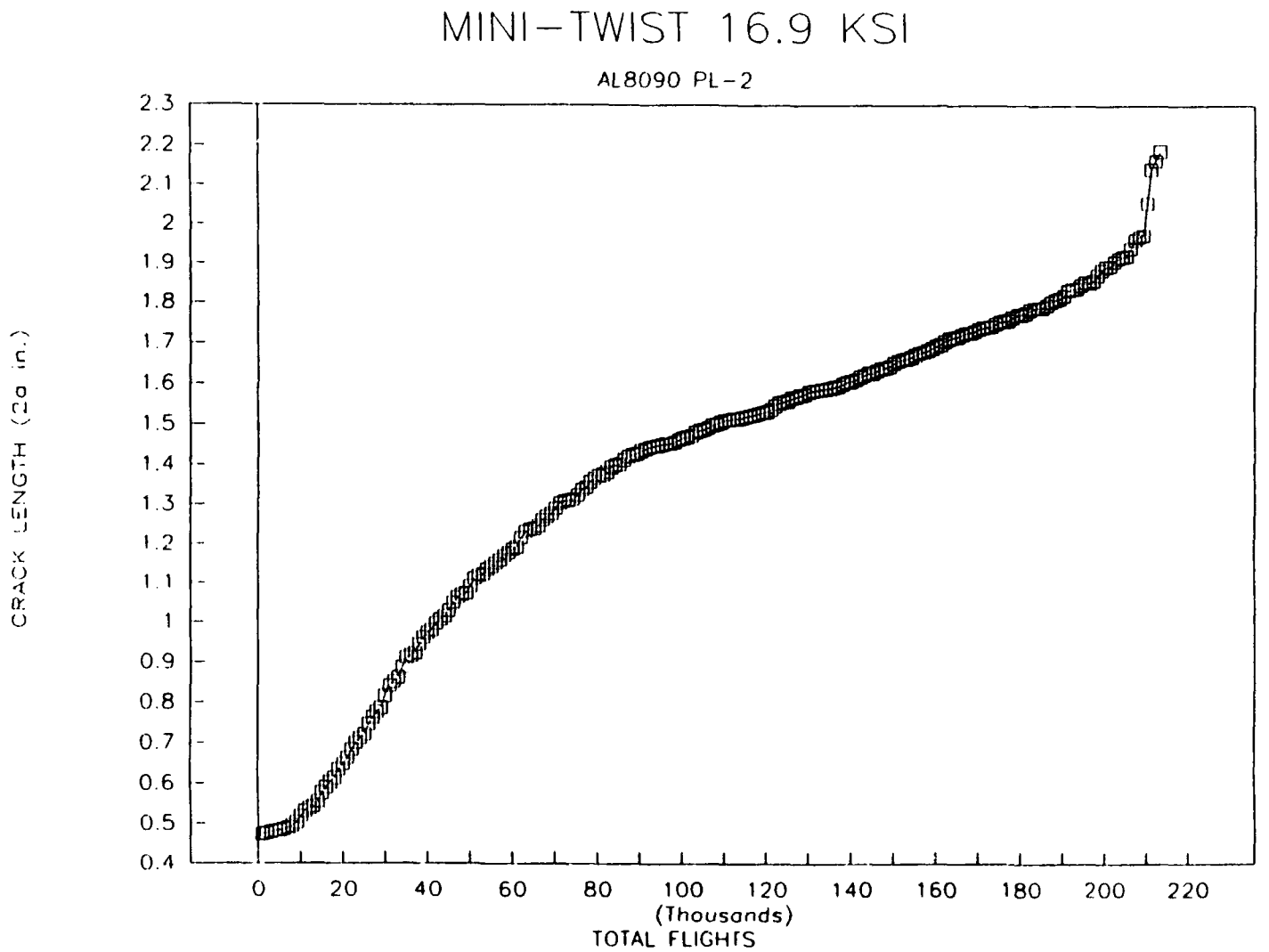

FIGURE F9. Mini-TWIST Spectrum Crack Length vs Flights Data for 8090-T8771 Plate (L-T Orientation, Room Temperature, Lab Air and Maximum Stress = 16.9 Ksi). Air Force.

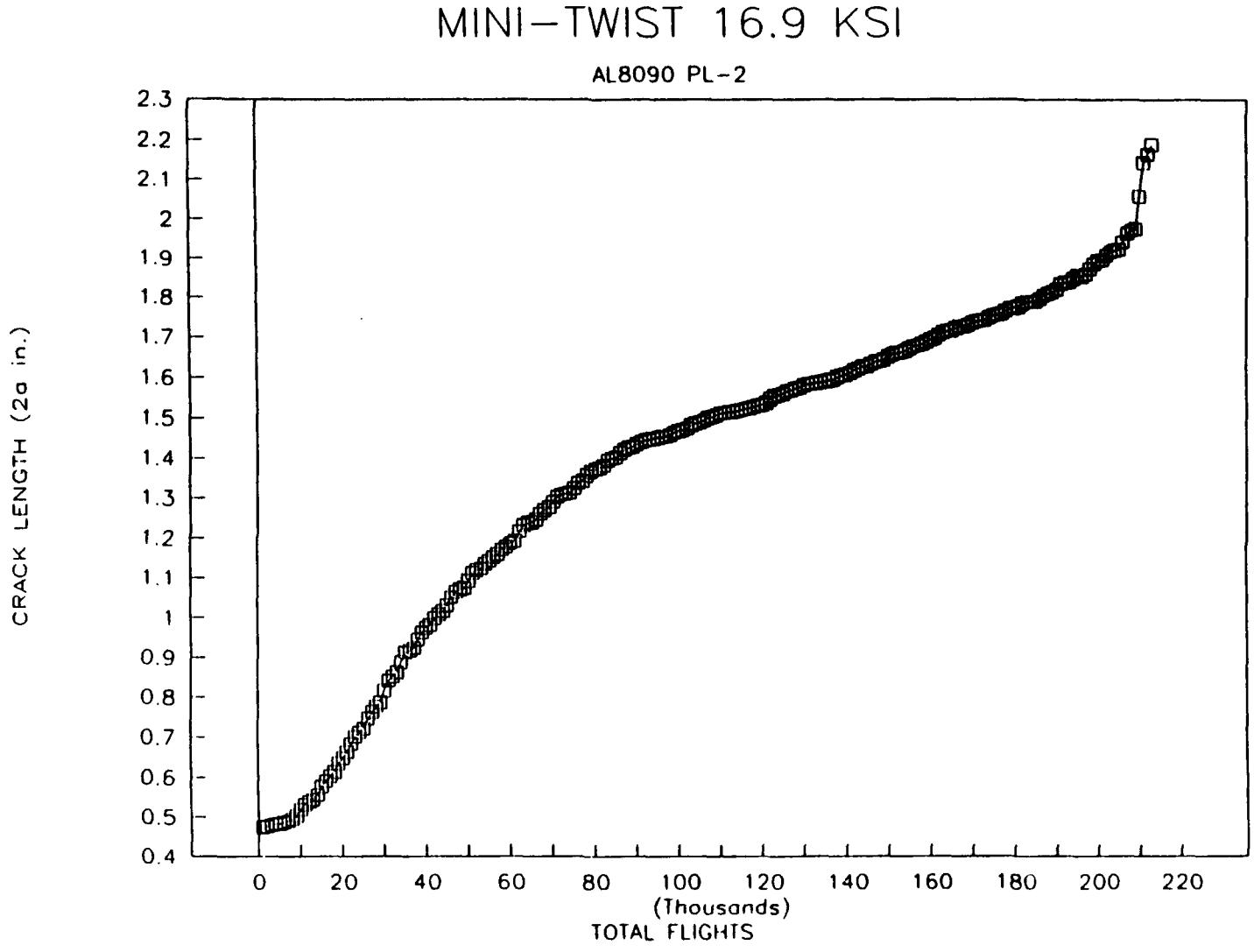

FIGURE F9. Mini-TWIST Spectrum Crack Length vs Flights Data for 8090-T8771 Plate (L-T Orientation, Room Temperature, Lab Air and Maximum Stress = 16.9 Ksi). Air Force.

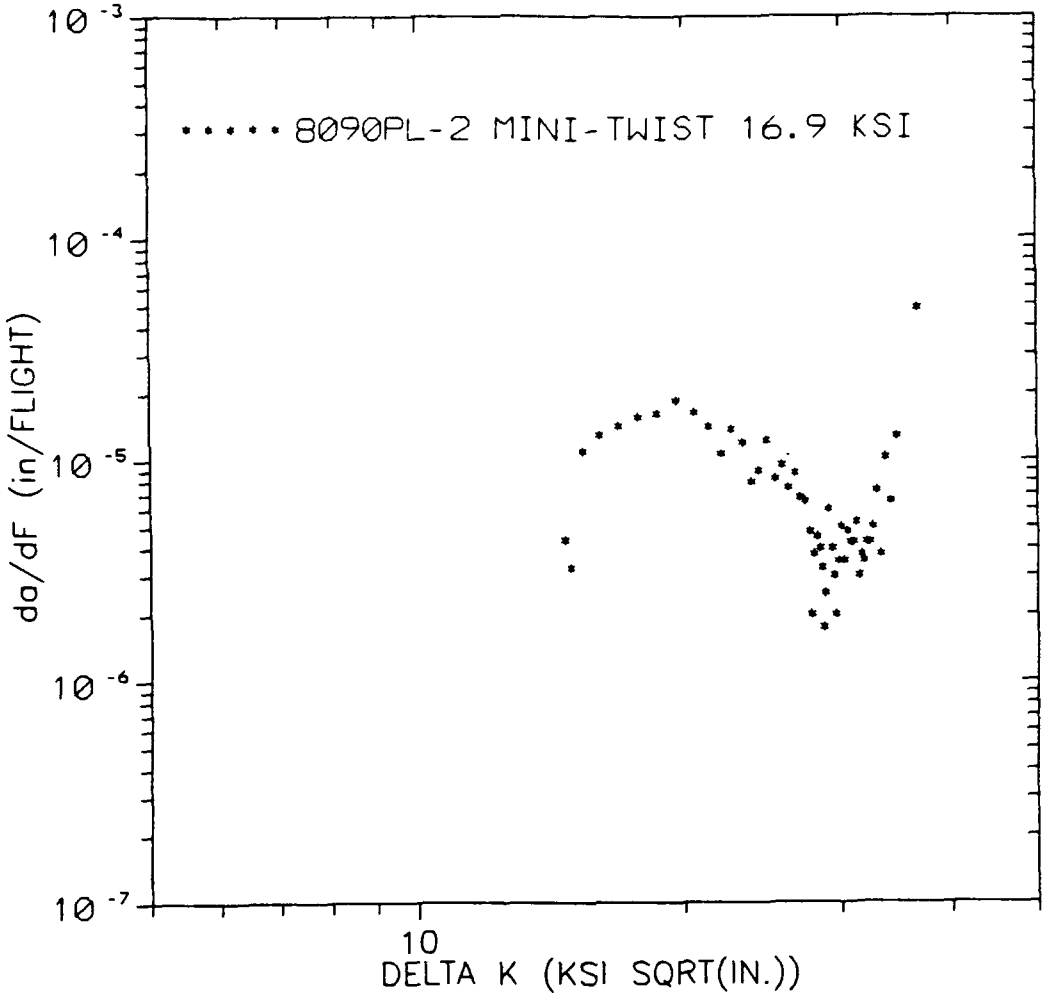

FIGURE F10. Mini-TWIST Spectrum Crack Growth Rate vs Delta K Data for 8090-T8771 Plate (L-T Orientation, Room Temperature, Lab Air and Maximum Stress = 16.9 KSU).
Air Force.

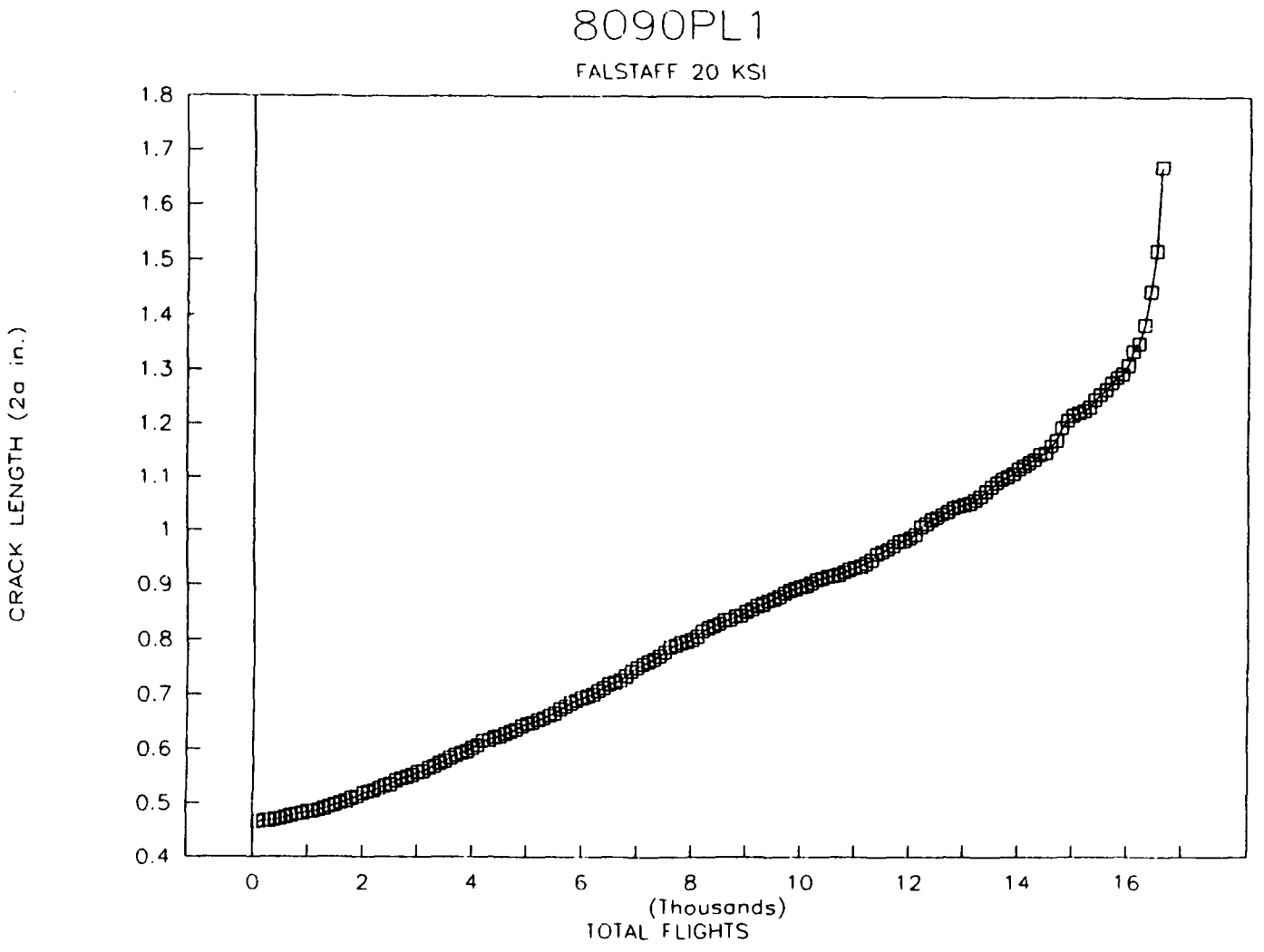

FIGURE F11. FALSTAFF Spectrum Crack Length vs Total Flights Data for 8090-T8771 Plate (L-T Orientation, Room Temperature, Lab Air and Maximum Stress = 20 Ksi). Air Force.

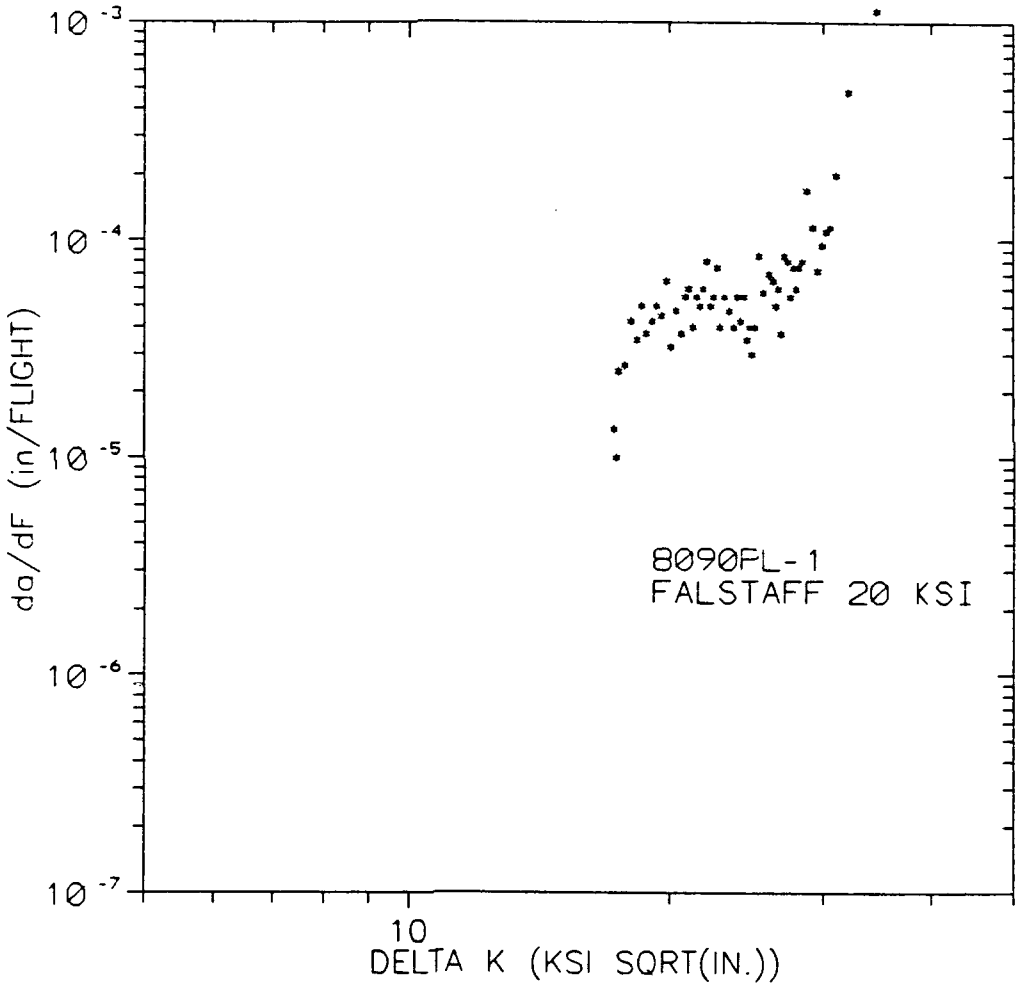

FIGURE F12. FALSTAFF Spectrum Crack Growth Rate vs Delta K Data for 8090-T8771 Plate (L-T Orientation, Room Temperature, Lab Air and Maximum Stress = 20 Ksi).
Air Force.

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